SOME THOUGHTS AND SUGGESTIONS

ON

Technical Education.

BY

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NEW YORK CITY.

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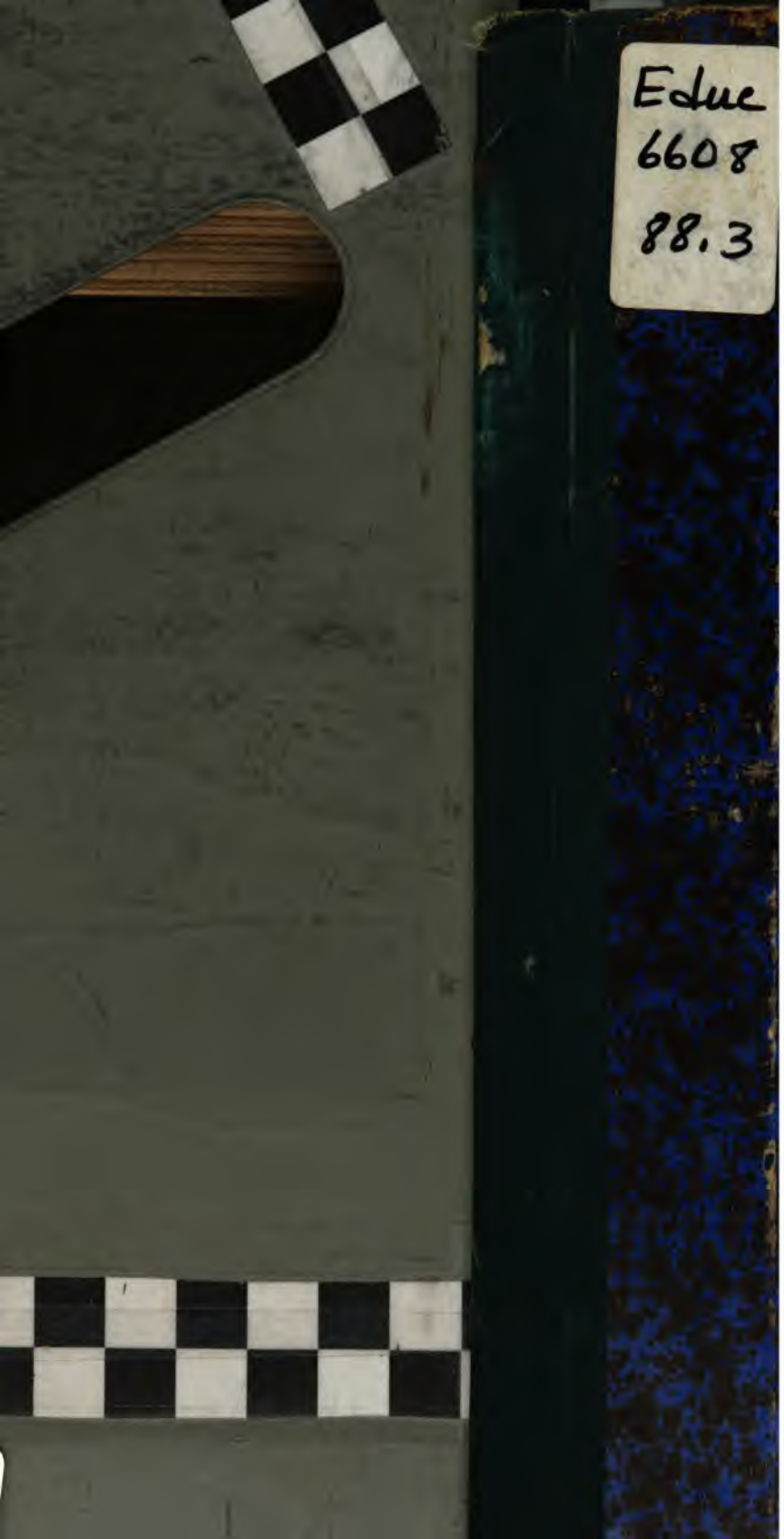
FOR a great part of the progress of the world we are indebted to the works of engineers. It is to them that we owe our means of rapid transportation, our canals, our railroads, our bridges, many of our automatic machines, and most of those appliances which by facilitating or decreasing the amount of human labor to be expended and by utilizing the great forces of nature have made the present progress of the world possible. Their education is a matter of momentous interest to the whole civilized world. I have, therefore, thought that some discussion of the theory upon which their education should be based would be of interest to this body, and have ventured a few reflections and suggestions upon the subject.

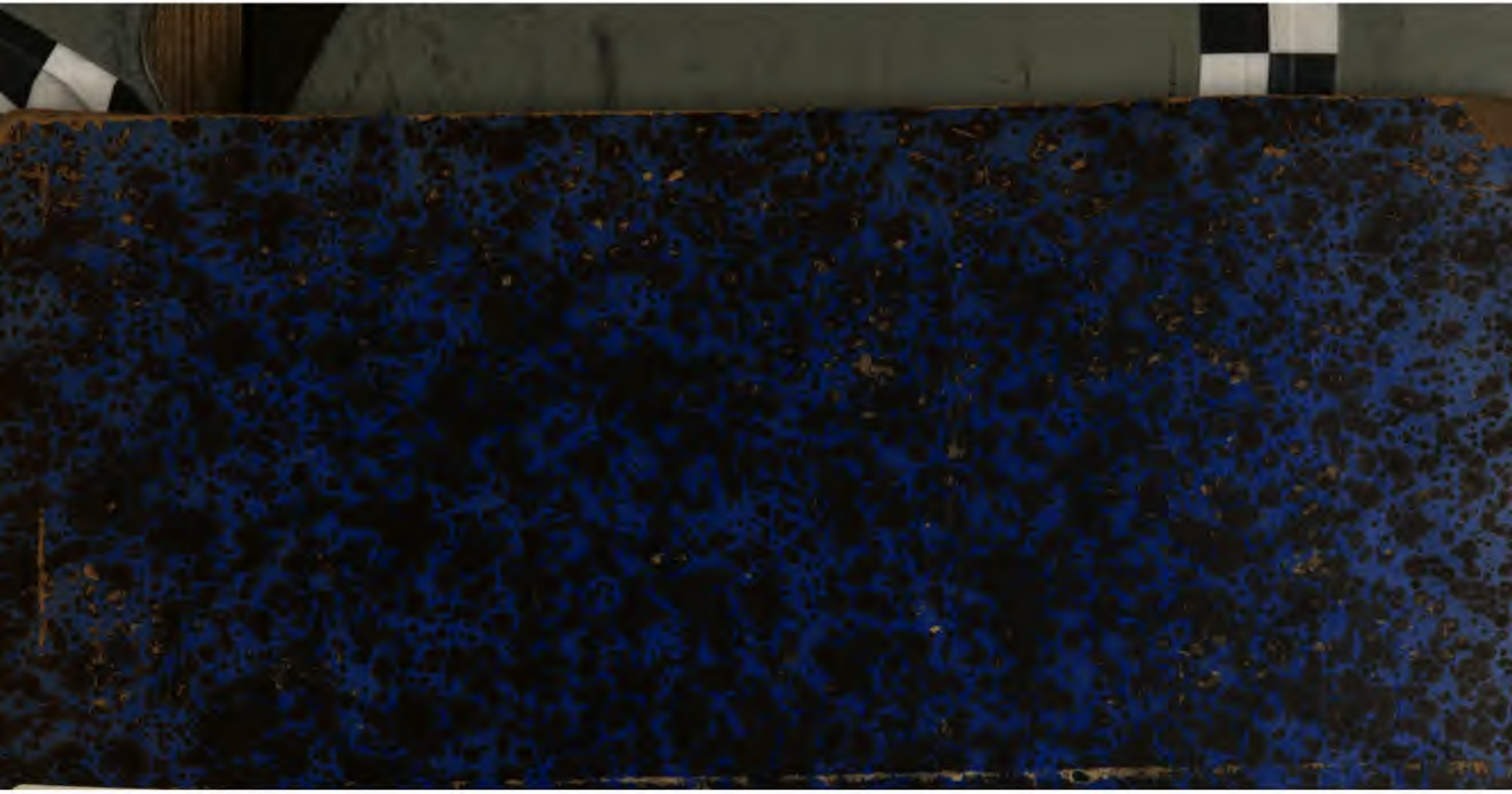
The word education, in its original signification, meant the drawing out of a man what there was in him. In our common schools the practical work of education consists in putting into the brain a larger number of facts than can be retained, which are consequently more or less understood and digested. It ordinarily consists simply of teaching a round of abstractions or facts which when not assimilated are not only useless to the individual, but generate careless habits of thought and make more or less untruthful, unfaithful or unsuccessful men. In most of our schools a procrustean system is adopted; all are made to advance upon one general plan, the quick being kept back and the slow dragged on at a rate too great for their power of comprehension. Until within a very few years it has been a theory in common school education that the brain alone should be developed, and that little or no attention need be paid to the training of the other parts of the body, so that the eye, ear and hand which, for practical life, are the most important parts of the body, are left, we might say, entirely uneducated. The child is constantly told that to make his manhood successful he must *do* something, yet no training is given to any part of the body with which action is possible. So far as the rest of his faculties are concerned, hir

brain is an abnormal development. On the one hand he is taught to "live by his wits," and on the other that a person who does so becomes a byword and a reproach. But true education should bring about the harmonious growth of the whole man, and not a one-sided development of one or two of his faculties.

With this system there has been for some years a very general distrust and an effort has been made to break away from it and replace it by some other method. That it has not fulfilled what was expected of it is patent to almost every one, and should we judge of it only by results, as we should judge anything else, it would seem at once that it was, to say the least, not satisfactory. It has been so long the habit to declare that our public school system of education is the foundation of all that is good in the country that it is difficult to look at it in any other way. We have only, however, to compare the results of such training with those of our own profession to see that it must be very defective. I remember in the year 1860 having heard my father, then 60 years of age, say of the men who started in business with him as a boy, that 90 per cent. had failed at least once, and that by far the larger part of them had never succeeded in obtaining even a competency. I have since heard the estimate of failures placed much higher. These men had all been educated under the theory then most common in the schools. No such statement could be predicated of the engineers who started in life at the same time, nor of the education which was given in the engineering schools. Any such percentage of failure in their graduates would have wiped them out of existence and consigned them to oblivion long ago. It is remarkable, in view of the fact of the constant failures in the common school education and its manifest unfitness, that attention should not sooner have been called to the adoption of the methods used in engineering schools, and that it should have required so many years to turn attention to the fact that there was something decidedly lacking in the inception and execution of our general school system, and more especially that it was training our youth in such a one-sided manner that brain development only was regarded as the legitimate object of education.

Bacon has said that education is the cultivation of a just and legitimate familiarity between men and things. Judged by this standard it must be said that our common school education is lacking in some of the essentials which bring about this familiarity. Facts in themselves are of no value; they are only important when they are applied. Mere thought in itself is of no use; it only com-





if it had never been in existence before, while to the man of the schools it is only another phase of a problem with which he is more or less familiar, or if he is not familiar with it at all, the mental discipline which he has acquired fits him fully for mastering it. I have, and always have had, a great esteem for the practical man in his proper place and rightly understood. He has acquired his knowledge by rule of thumb, and knows only the experience that he has gained in particular cases; but he has usually learned by this experience so well and has cultivated certain of his powers to such an extent that he is generally only at fault where his experience fails. If he has had a number of special cases and been successful in them he may be successful again; but his knowledge is almost always empirical, his experience confused and confined within very narrow limits, but when with his practice, his powers of observation have been cultivated and he has learned to reason he rebels against the name of practical and becomes at least the skillful man, and when, as is sometimes the case, he carefully studies principles, he becomes an engineer. I have nothing to say of the abuse of this word "practical" by men who use it to cover up ignorance.

The education of engineers, however, has been usually better conducted. They have not only had the receptive faculties cultivated, but the eye, the ear and the hand have been so trained that a failure with them is uncommon; and it is to this distinction between the education of engineers and ordinary education that I wish particularly to call attention. Until within a very few years France has led the world towards solving the problem of technical education. The reason for this was not only on account of the proper system and the greater advantages which were given to the students, but was also due to the fact that a system of selection by examination was adopted. Commencing at a very early age, the children all over the country were sorted and resorted until when they arrived at sixteen they were definitely classified into those adapted for the various professions and were then sent to the different technical schools supported by the government to be trained and after graduation were again re-selected, according to their capacity or ability for the different branches of each profession. Such a system raised education in France to the highest point it has ever reached and produced some of the most profound thinkers and investigators that have ever been known. In Germany great stress has always been laid on what they call their "*practicum*." Their success consisted in training men in the schools in what they would

be called upon to do as soon as they left them for practical life. It is to the combination of these two systems, a careful selection by examination and the practical training both in and out of the schools, that the most of our success in educating engineers has been owing.

These methods, which we are constantly amplifying and improving, we call scientific. They have grown with the results of experience, but to most men science, which really means only knowledge, is regarded as just as fixed and positive as mathematics, while in fact, as science is only knowledge, its value is in reality only relative. We are constantly told, "these are the deductions of science," as if they were perfectly mathematical and certain; whereas the best science of the last century would be dense ignorance in this, and what is scientific and true to-day, with the knowledge we have, may become to-morrow, when further facts are discovered, entirely untrue. Science is really only a round of invention and discovery. With the knowledge that we have we reason and conclude, until we find by experience that our reasonings are false, since the results are not true, and then, with the facts that we have at our disposition, we are obliged to take up some other theory. It is this high endeavor to ascertain what is truth and to apply the principles which are involved in it, which make the active searcher after truth, and ought to develop the character and make high toned men, and it is to this constant adaptation of our technical school system to the needs of the day that its superiority is owing. Could the same be said of our common schools we should have less fault to find with them and there would be fewer failures among their graduates.

All education should tend to the development of the reasoning faculties in such a direction and in such a way as to enable a man rapidly to determine what truth is, and then if the eye, the ear and the hand have been properly trained, knowledge and experience will give him the power to apply it. As such an attainment is a matter of the highest importance I propose to call your attention to what I consider to be some of the defects and advantages in technical education, in the hope that from the comparison some suggestion may be made towards an amendment in its system and lead to the adoption of a different method in our common schools. Our technical schools are designed to train engineers. But what is an engineer The people think of him as an engine-driver. The dictionary says he builds engines of war and steam-engines, or constructs roads and bridges. In England he is a constructor of almost anything. There is need of a better definition in these days, when we have military,

civil, mechanical, mining, chemical, sanitary, and electrical engineers. These men originate and design what is adapted to new and constantly varying conditions, apply old principles to the solution of new problems, and keep the world constantly advancing. In those parts of the world where there are no engineers, civilization either retrogrades or is at least stationary. There are so many special traits of character which distinguish engineers as a class, that it is most interesting to study how they have been formed and especially to observe how the habits of accuracy and love of truth have been and are to be developed; and I have thought it would be appropriate to discuss how engineers should be educated.

In most of our schools, if not in all, the requirements for admission are too low. The student enters so badly equipped that from a year to a year and a half is expended in teaching him the mathematics and other preliminary studies, which he must use in the later years of the course, so that any application of these studies must be confined to within a little less than half of the entire school-training. The justification of this course has always been in the assertion that the preparatory schools cannot be made to raise their standard sufficiently high. Yet during the last twenty years their standards have been raised; and it is to be hoped that at least a whole year of instruction in the technical schools may in future be gained by demanding for admission to them, mathematics up to and perhaps including the calculus, so that the applications only of mathematics may be taught in these schools. The same might be said of some of the other preliminary studies. If this were done gradually, I think there would be no serious difficulty in increasing the value of technical education without lengthening the course of study and practically securing what would now be equivalent to a five years' course by throwing out into the requirements for admission a whole year of the present instruction. This would permit, at least in the last year of the course, the practical application of the principles taught, and the introduction at that time of a commencement of actual professional field-work, and especially the more extended carrying out of the principles of engineering as applied to constructions executed on a large scale, and the introduction of the practice of the principles of design, so as to teach the student what can or cannot be made in wood or metals and the general application of these principles to economic construction.

A knowledge of French and German is absolutely essential to success in any professional career; and as this knowledge is wanted,

not only in the school but out of it, it seems proper that it should rather be demanded as an entrance-requirement than that instruction should be given in these subjects in the school. For many years, in the institution with which I am connected, instruction in French and German was given as a part of the school-course, but this method finally had to be abandoned and it is now placed in the requirements for admission. It was found almost impossible in the early days of that school to get the preparatory schools to promise beforehand to undertake instruction in this department, but since we have required it there seems to be little or no trouble in inducing them to do so and a great deal of time is thus gained which is now devoted to other important subjects. It seems much more rational that it should be required for admission than that it should be taught in the school, for a very large part of the investigation that is being made on professional subjects and a very large number of valuable communications which are being presented to the scientific societies and the periodicals are published in those languages; and as there is constant occasion to refer to them, the student is absolutely at a loss in this matter unless he can consult easily and without much expenditure of time such periodicals, which become of course a terra incognita, unless he is sufficiently familiar with these languages to read current literature fluently. The change made in this respect has been to us most beneficial and I think would be likely to prove so in other institutions if it was adopted. The teaching of languages also seems to be rather foreign to the objects of a technical school. At any rate we have found the greatest advantage in devoting the time that was formerly given to it, to strictly professional studies and demanding that the students entering should have a sufficient familiarity with these languages to be able to read current literature. Such studies as history, geography, logic, rhetoric and English composition are quite as necessary to engineers as to other men and where collegiate education cannot be had, should take, as far as possible, the place of such instruction, and in order that the young engineer shall have something equivalent to a colligate course, these should also be required for admission. Composition, which means the art of expressing thought, ought to be not only required as an entrance study, but should be fostered in all the written exercises of the school. A drawing speaks for itself if made in sufficient detail. It is made in the universal language which has within itself all the logic as well as the rhetoric of the schools, but composition gives the means of expressing concisely and logically in words ideas which thousands, who do not under-

stand that universal language, can comprehend. It also gives the power of setting one's own thoughts logically and tersely in order, and is one of the best means of ascertaining for the engineer both what he does think as well as what he ought to think, and is often a better means of convincing himself than of persuading others. A plain, terse style of composition is a mighty weapon of war which engineers, of all men, use to their own hurt if they do not use it right. In any case such training ought, if possible, to be acquired before entering the technical school as will be to a great extent equivalent to a university education. It would be impossible, of course, to obtain the whole of it, but there is great need that more attention should be paid to this subject in our technical schools, in order that we may have cultured as well as educated men in the profession. The remarkable unanimity with which all those who in 1876 joined in the discussion on technical education before the Institute at Philadelphia, demanded the greatest possible culture in the applicant for admission to our technical schools, showed how necessary in the opinion of every engineer, long in the profession, this previous training and its consequent culture was thought to be, for successful professional practice. There is a real lack in most of our technical schools in that moral science is neither taught nor required for admission. It has been left out in both places partly through inadvertence and partly because in the early days of the establishment of technical schools in this country most of the students came from the colleges, and therefore had this training; but now that the tendency is to replace the college by the technical course, attention ought to be given by our educators to the fact that certain studies of the university which promoted especially certain moral qualities are now entirely neglected. They are not taught in the preparatory schools and are left out of the technical course. It may be said that these moral qualities are produced by the constant search after truth, which the engineer must of necessity make in order to be assured of success in the practice of his profession; to which it must be replied that moral qualities are usually the result of education and that where the principles of morality are not taught directly the indirect teaching of the laboratory and workshop and the endeavor to apply to actual practice the great principles which result from a constant study of the forces in nature do not of necessity create a thorough understanding of the basis of those moral principles which are necessary to the well-being of a man. Some provision ought therefore to

be made, either in the school or in the requirements for admission, for the teaching of the general principles of morality.

One of the chief things which force themselves upon the attention of the instructor in the scientific school, is the apparent disadvantage which the college men appear, at first, to have in comparison with those who have only received what training they have in the scientific school, and it seems sometimes as if the advantage of a college education was very much overrated. It has, however, been the constant experience of the institution with which I have been connected that the culture which the college man has, while it does not show in the preliminary years in which mathematics are almost exclusively taught, makes itself felt the moment the applications of principles come to be made, and shows itself constantly in the practice of after-life.

But the old university education was only a preparatory training for the "professional schools," as the schools of law, medicine and theology were formerly called. At first the technical school occupied a position similar to the "professional school" with excellent results. No university man who has graduated at a technical school, and has employed his time at the university well, can call it wasted. The profession has still every reason to be proud of university men who have supplemented their education by a course in a technical school. It would be greatly to the advantage of such technical school if entrance into it could be preceded by a university training; but as we are every year diverging more and more from this practice, and as now such double training is not generally practicable, there is gradually ceasing to be any intermediate between the common and the technical school. The object of the technical training is now to fit one for practical life at an age younger than that at which men usually graduate at the university. The university course has been supplanted by the more or less perfect instruction in the common school, and the technical school for the engineer now supplants the university, and he thus enters upon his technical school training without any such preparation as the professional man, as he was formerly called, had. How shall we supply to the applicant for admission to our technical schools the training which the young man entering the schools of law, medicine, and theology from the university is supposed to have? The answer to this question is plain, and it is the only one that can be given. It is by requiring for admission to the technical schools a high standard of attainment and such studies as shall be fully equivalent to the engineer for the loss of the univer-

sity training. Among these requirements should be included the elements of rhetoric, logic, moral and intellectual philosophy, political economy, history, English composition, and at least two of the modern languages. It is hardly to be supposed that all of these could be taught in the common schools to the same extent as in the university, but their elements could be. There would, then, be much less danger to the engineer from the want of thorough acquaintance with these studies if he was drilled in the elements, since it is his peculiar province to know how to find any information for which he has need. The want of a knowledge of the studies opens up a real danger, of a one-sided training, and the want of a proper acquaintance with correct moral principles. As we have thrown over the old university system of preparation, we must replace those parts of it which relate to the training of moral qualities by preparatory studies in them, and supply the want of the training acquired by the study of Latin and Greek by at least their equivalent in other studies, in the requirements for admission. A low standard for the entrance examination will undoubtedly at first increase the number of applicants for admission, but numbers are not necessarily a criterion of success. They may, on the other hand, be a very decided sign of weakness. It is certainly true that that institution which offers the best advantages to the student will be the one which will in time be the most patronized, and that, in the long run, perseverance in demanding a high grade both for entrance and in the studies of the school will be crowned with success. But success does not always mean a large number of names on the roll-book. Numbers may, and frequently do, imply a low standard, the quality of instruction being lowered in order to get a large number of students. Such a policy must eventually result in disaster, both to the students and to the institution. It is referred to, only because, in the intercourse which I constantly have with members of boards of trustees of institutions all over the country, almost the only criterion of success which they seem to appreciate is numbers. I think I have never been asked by trustees of institutions, either in the east or the west, what the grade is; but I am constantly asked, as if it was the only criterion of success, what the numbers are. It is only when the highest possible standard is maintained that numbers become a sign of strength. A high standard should be maintained and enforced both for entrance and during the years of the school. It is no charity to launch into the profession men barely prepared to enter it. This does not mean the exclusion of any slow-thinking students who

would enter the profession for the love of it, but require a little more time to accomplish their work, but only of those who look upon it with little or with dilettante interest, are careless and indifferent about their work, or are unfit for it; and it throws the burden of labor on the preparatory schools, which must raise their standard accordingly if the entrance standard and requirements are higher. Not to maintain a high standard in the school is the greatest possible want of charity to the students, for a man insufficiently prepared to enter the profession is launched into it in a more or less crippled condition, and is liable to make failures which will be disastrous to himself and others. Almost the only way in which a high standard can be maintained in the school is by demanding a high attainment both to enter and remain in it. It would be better for the whole country if every school would adopt the principle of the old Paris School of Design, whose authorities were entirely satisfied if they turned out but one first-class man in a hundred every year, and who did not consider that their work was useless if they failed to produce one, if the cause of failure was the want of the attainment of that excellence at which they aimed to arrive. Our system differs from that of most other countries in the fact that the greater part of our schools receive no aid from government, and that comparatively few of them are sufficiently endowed to be entirely independent of the fees of the students, while in many cases they are mainly dependent upon this support. The temptation, in such a case as this, is to yield to a low standard, and it is sometimes done, but always with unfavorable results which are sometimes fatal. The engineers of this country owe a debt of gratitude to West Point, which for many years was almost the only engineering school in the United States. It has never lowered its standard, which as a government school it could easily maintain. They also owe a still greater debt to the Troy Polytechnic School, all honor be to it, which, being dependent on fees, has nevertheless maintained from its commencement one of the highest standards known in engineering educational institutions, and has turned out many a man who has been an honor to himself and his *alma mater*.

Of the methods of instruction, the lecture-method combines the necessity for discriminating between what must be noted and what may be neglected—unflagging attention and rapid thought, with the manual power of noting it. The student ought to be taught to take his notes in such a way that they will not require rewriting. It must be said against this method, that it requires that every one should

go at the same pace. With the printed text-book, or autographed notes, which answer the same purpose as lecture-notes, there is this great advantage, that the men can work fast or slow, according as they are capable of taking in the subject with more or less rapidity. They can go as fast as the lecturer, or, if they cannot follow, they have something to guide them. The textbook system is either expensive, or the book is behind the times; and it calls into play the eye and the memory only, while the lecture system requires the use of the ear, the eye, the judgment, and the hand. The autograph system of the French, which provides the student with a manuscript copy of the lecture-notes, to serve to some extent the purposes of the text-book, is an excellent one; for the student can read over the matter to be discussed before he comes into the lecture-room, and then expand his notes if desirable. Such publications can always be kept up to date, as they are not expensive, and they can be modified from year to year, while large editions of the text-book must be made in order to make its publication commercially profitable, and it necessarily remains for years unchanged. It may be said of all classes of text-books that they cultivate the memory almost exclusively, and that recitations made from them give the school-boy "feel," and do not cultivate the independence of thought and action which is necessary in the engineer. By the introduction of quizzes, or repetitions as they are called by the French, into any kind of instruction, the lame ones are brought up without the necessity of keeping back those who are able to work rapidly.

Every effort should be made to break up a system which uses the memory without the judgment; and, for this purpose, examination-questions should be those which involve the use of reason rather than memory, and, consequently, not on the details of subjects directly treated upon in the lecture-room, but only on the principles that they involve. I think too great stress cannot be laid upon this principle. It not only involves the habit of reasoning, but the habit of correct expression. A parrot can master words, but only a well-trained mind can master principles. I can remember very well, in my university experience, mastering page after page of subjects by rote, because I was compelled to, without seeing until long years afterward the principles which those words involved. If both the instruction and the examination had been upon principles, the principles would have remained while the words were forgotten, and there would have been a large amount of intellectual force saved. It

should never be forgotten that the object of education is not to go through a series of mental gymnastics which tend rather to overtax than to invigorate the brain, but to train the mind not only to receive facts and principles, but to be able to discriminate between what is true and false in what is presented to it for discussion.

One object of the instructor should be, not so much to answer the question of the student, as so to direct his inquiries that he will answer it for himself. There are, however, many cases where the allowing of the student to work longer would be a waste of time, and the instructor must therefore ascertain when the student is to be told, when he is simply to be directed, and when he must be left to himself to answer for himself. Just where the point comes when the instructor must answer a question instead of directing the student must be left to each instructor, who must know not only the man but the difficulties which each student is likely to encounter in his study of the subject.

There are a large number of principles which must be well taught, and insisted on at the very start. Accuracy of statement and the power of concentrating the mind for considerable periods on definite subjects are essential, and these are given by the study of mathematics. The constant care which is necessary in making demonstrations and proofs, brings about very largely an accurate habit of mind, but, on the other hand, has the tendency to make the mind demand demonstration, and to deaden or destroy the imagination. But a well-regulated imagination is indispensable to every engineer. It is necessary for him in his constructions, and in his application of old or in his development of new principles, and is a bad quality only when it is uninstructed and unregulated. There are many ways in which the accuracy of statement gained by mathematics may be effectually preserved without destroying the qualities of observation, of judgment and of imagination which are so necessary to the success of every department of engineering. These qualities are gained mostly in laboratory work and museum study.

The being compelled to seize at sight slight differences of shades of color, in making chemical researches; to make the distinctions in the tints formed by superposition of coats on coals with the blowpipe; to distinguish, like the spectroscope, mixtures of colors from simple colors; the observation with instruments of what the unaided eye cannot see; the reading of scales and micrometers, and correcting of very slight errors in mathematical researches, in which great accuracy is required, gives that intellectual power which first delib-

erates, then reasons, then generalizes, draws certain and fixed conclusions, and then makes their applications and permits at the same time of the legitimate use of the imagination. It is to such accurate laboratory work as this that we must look to prevent the deadening of the imagination which a too great predominance of mathematical studies would result in. These studies should, therefore, be supplemented by those in which there is something to do which requires the use of the imagination, and of the eye and of the hand at the same time. Another, and sometimes an equally desirable method, is to dwell at some length upon the lives of great engineers, the steps and methods by which they attained their success and celebrity. This will both fire the imagination and the ambition of the student, and lead him to think what he must do to arrive at similar success.

In order to see, one must be trained to look. To be able to see so accurately that the impression on the retina of the eye will be so perfect that it can be accurately transferred by the hand to paper, produces the power of self-reliance, promotes the habit of close thought, and searching for the principles on which everything that is to be represented in the record of instrumental observation is made, or in the drawing of the thing seen is to be constructed. It promotes accuracy of expression, both of the hand, the eye, and the tongue, and thus indirectly affects the moral well-being of the man by promoting a real love of truth. The powers of observation and of judgment are cultivated most thoroughly by watching the various colors in the blowpipe-work, the effect of their superposition, the way in which the coats come one after the other; by noting the characters of minerals to distinguish, not only their color, but the various tints of color, the luster, the shape, the usual form and the associations; by looking for the slight variations in crystals which distinguish one system of crystallization from another; by watching the differences of action in different motions in machines; by sketching a machine or its parts from memory; by ascertaining the exact time when the tool must be withdrawn from the lathe in order to make it possible to finish the piece without making it too large or too small; by the careful inspection of gauges and reading of scales, and the fitting of all detached parts within very restricted limits—and in a thousand other ways, in which the pupil can easily be trained, and in which he unconsciously trains himself when he has been properly directed. To further aid the development of these faculties, he should be taught not only the careful observation of chemical, physical, and mechanical phenomena, but also accurate

methods of recording them. This is greatly aided if the record is made on a series of carefully prepared blanks on which the phenomena are required to be described in a given order, and conclusions are required to be drawn from the data observed, which accustoms the pupils to systematic methods not only of observation but also of record. The peculiar advantage of eye-education is, that the eye sees and telegraphs the mind, the mind calls the judgment into play, which telegraphs the hand what to do, and tells the voice what to say. This education of the eye to observe the minutest differences in things, even if they have no bearing on the profession, gives the power of quickly detecting those very slight changes of action or of appearance upon the observance of which life may sometimes hang, and at the same time the discrimination which directs the remedy. Eye-training stimulates the brain to activity, which in turn makes the hand as well as the eye accurate. It is a slow process, acquired gradually and almost imperceptibly, and finally brings about that discipline of mind and hand which makes the hand work instantaneously with the eye, the eye directing while the hand executes the thought, the action being at the same time instantaneous and accurate if the education has been properly done. It also affects the whole moral character, for the indirect teaching of constantly making careful records of observations must lead not only to accuracy of method but to a real love of the truth for its own sake. Those who are so trained must be truthful as well as accurate, for accuracy means truth. The necessity for professional truth will thus become a part of the man and will influence his whole life.

Every savage diligently cultivates his powers of observation. His life depends upon it. The bent twig or compressed grass, the abrasion of the bark, the turning of a stone, and many other indications that would pass unnoticed except by one whose powers of observation were cultivated to the highest degree, tell him a clearer story than our printed page. It is only civilized man, who is so constantly served that he need not always depend upon himself, who must be urged to observe and made to see that careful training in that direction is necessary. Yet men always admire the application of these faculties when they have been cultivated. How many lives would have been saved if, in cases with which every one of us is familiar, the powers of observation had been so cultivated that every slight change in color, which in iron or steel precedes its rupture, or the tremulous motion or slight crack, or many other small phenomena which give warning of danger, had been perceived before-

hand, instead of allowing the accident to take place. Life is full of illustrations of the infinite harm done by careless observation or the entire want of it. To the engineer it is one of the most important faculties he can train, and the keen quick perception which he acquires in this way makes him foresee and correct the evil, stimulates him to prevent rather than cure, and gives him the skill which the world both appreciates and admires.

I do not think that the importance of drawing as a mental discipline is understood by most of our educators, nor sufficient time devoted to teaching it. It is generally treated more as a means to an end, a tool that one is to use as occasion requires, rather than as a method of acquiring mental discipline. I fear from the purely mechanical way in which it is taught that it is regarded more as a hand labor, than as one of the best means by which accuracy of thought and expression is to be attained. To be able to put into one of the universal languages, drawing, the idea that one has in his mind, so accurately that it is incapable of misconstruction, and that the thing or machine can actually be made from it, shows mental discipline and control of mental force already acquired. To see in space not only the thing itself, but the sections of any of its parts in any plane, and then construct what is seen, means great concentration of mental power, as well as confidence in the ability to use it.

I wish that I could make every child learn to draw just as soon as it is capable of holding a pencil. It is just as absurd to say that it requires a special talent to draw and design as it would be to say that there must be a special talent to learn the multiplication table. In a series of experiments on this subject, made some years ago, it was found that facility in drawing greatly aided the ability to master other things. The mass of the world looks but does not see, which is well illustrated by the fact that two persons of ordinary education looking at exactly the same object would describe it differently. The habit of sketching freehand and of making drawings tends to develop accuracy of the eye and its comprehension at the same time. To be able to see what one looks at is one of the most valuable attainments which it is possible for any man to have, and there is no better way of gaining it than by carefully observing and then sketching what one has seen. The hand shows what interpretation the eye makes of what it has observed and how much of the principle has been mastered in the attempt to see. After a few unsuccessful trials the tyro learns just how far he can trust his

eye, and then educates it up to a higher standard of accuracy. The eye must be aided by the memory, and thus the eye, and the memory, and the hand are stimulated and exercised at the same time. One of the best methods of cultivating this habit of accuracy is by making drawings from real objects and plans and sections in various directions, which not only gives the ability to be able to see what is looked at, but to look into and discuss and criticize in the section what cannot be seen from the outside. It also makes it possible to represent to others the most complicated thought, so unmistakably that the workman who never thought of the idea can execute it as well as the originator of it. The habit of accuracy once learned in mathematical demonstration and in the execution of sectional drawings results in a habit of mind which tells not only on the man but on all those who come under his influence. The constant dwelling on problems and things with the object of arriving not only at the truth, but at an absolutely accurate representation of the thing which is to be either executed or described, forms the habit of judging of things according to their real value, discourages superficiality in reasoning and shams in construction, and does away with the possibility of making the cheap substitutions and subterfuges which often pass for original and accurate thought and consequently develops the love of truth for truth's sake.

To gain facility of seeing what the meaning of a drawing is and to learn how to see what is to be shown in the sketch, models must be used by the beginner. The facility for drawing is greatly aided if after the sketch has been made the model is taken away and the same drawing is made from memory, with the same dimensions and proportions as nearly as possible. It is astonishing how quickly the eye is educated under such circumstances to take in not only proportions but minute detail. Freehand sketching taught in this way gives a power of memory which makes quick and accurate observation possible, and eventually leads to the habit of making the preliminary sketches in such a way that long after the object sketched has been forgotten the scale drawing may be made from the sketch with as much accuracy as if it had been made at once. Freehand drawing makes the brain express through the fingers what it could not express by the mouth or by any amount of words. It leaves the thinker, the designer and the engineer to make his rough sketch, which can afterwards be transformed by the draughtsman, in any part of the world, whatever its spoken language may be, into the scale drawing, which is understood in the shops where the sketch might not be, and prob-

ably would not be understood, and thus saves valuable time of the engineer to be devoted to other things.

There is no doubt that in most of our schools sufficient importance is not attached to engineering design. I do not mean the making of pictures which look well and the copying of drawings or the sketching of machines or the putting together of different parts of different drawings, but the original designing of something for a specified use, and the making of such drawings as would be accepted in any shop for construction. This is perfectly capable of being taught, and that it does not require such a very high standard of intellectual culture to design things that can be executed is shown by the experiment made in one of our charities in New York, some years ago, when children who did not even know how to hold a pencil, mere street Arabs, collected indiscriminately as they passed along our highways, were brought together in schools in different parts of the city, and without knowing that it was difficult, taught first to draw and then to design, so that in a few months these children were not only making such drawings as could be executed, but were themselves designing patterns, and after a certain time learning to be capable to earn their own livings, originating the designs which they were executing in wood, metal or clay, thus firing their own ambition and raising themselves more rapidly than could have been done by any other means. The same experiment tried on older persons did not succeed so well, though there was a fair measure of success with them; but just one hundred per cent. of the children were successful in making designs which were not deficient either in originality or beauty, and which could be executed in the material for which the designs were made. The success with these children was mainly owing to the fact that they had no preconceived idea, either right or wrong, nothing to unlearn; that they did not know that what they were being taught was difficult; and that their ambition was fired by seeing that they could translate both things and ideas to paper, and that when they were told to create, their imagination was allowed to have the greatest freedom, though directed by the experience of those who taught them. If such results can be attained with the illiterate, what might not be accomplished with those who have been carefully trained? A cultivated imagination, coupled with an educated hand, leads necessarily to design, and if the proper principles have been mastered, to that kind of design which leads to correct construction. It is a mistake, though a very prevalent idea, that designing re-

quires some peculiar talent. The child with good eyes and hands and fingers that were capable of movement, who could not design and did not attempt at some time in his life to draw has not been born. As a usual thing, the first attempts at design are laughed out of the child by injudicious relatives. Who knows, if the rude drawing of the man or horse had not been laughed at and the child discouraged, but his first efforts had been encouraged and his hand properly trained, but that he might have eventually benefited mankind with some construction that would have caused a real advance in civilization? The imagination of the child is vivid but untrained, and can easily be directed into the proper channels. Imagination is only useless when uneducated and falsely directed. It is really the first step on the threshold of the unseen, and when it is well-directed it makes this threshold the open doorway to invention and discovery. Without the power of logical reasoning it is like the engine without the fly-wheel, which either wastes its power or expends a large part of it in tearing itself to pieces without producing any adequate return for the force applied.

Different degrees of talent are given to different persons, but fair success in design is certain to every one who is properly taught, while inspiration is given to but a few. Real progress is made by untiring effort. Advancement would stop if it had to trust only to inspiration. Well-directed effort, the result of careful training and study, is worth more to the world than the inspiration of the few, the very few geniuses who cannot be depended upon. A profession must have constant action, not spasmodic effort. To this end design should be taught in our schools, and illustrations of what may or may not be done with given materials, aiming only at what can be executed, should always be given. This instruction should be supplemented and illustrated by the best examples which combine beauty with strength, and which teach at the same time the laws of proportion. Ugliness is repulsive both to the eye and, in almost all cases, to the real utility of the structure. It is never true that the greatest utility and strength must be combined with want of proportion; proportion is another name for beauty, and it is true that the lines of symmetry and beauty are usually those of greatest strength. There is no reason in itself why structures should not be beautiful instead of ugly, and with a proper cultivation of the imagination strength can just as well be combined with beauty as with ugliness.

The problems which are given in teaching engineering design should be selected with a view to excite the imagination as well as

to develop the intellect; for there is no place where imagination is more required than in engineering design. Its cultivation not only brings about the possibility of designing beauty of form, but, when well directed, gives expedients and resources not only for current cases of work, but also in time of danger, for the education of the eye, together with the imagination, causes the powers of observation to be cultivated and sharpened, induces reflection and promotes action. The certainty that one sees what one looks at, and that he can with security not only interpret what he sees for his own immediate action, but that he has the power of transferring this observation or that thought into such a language that it can be comprehended by almost any one, promotes self-reliance in the highest degree, and at the same time makes independent thought, if, as a student, the engineer has learned to have a personal judgment. We may say that quick, accurate thought, and the power of expressing it with pen or pencil, is the key to the preservation of life and the invention of most of the improved appliances.

Making designs which are to be executed, produces a kind of mental training which is of the very greatest use in after life. Every line then made involves the thought, not only of how it is to be executed, but how it will look after the piece is finished. It implies concentration of thought as well as discipline of the mind, the hand, and the eye, which makes the accurate man. The possibility of seeing in space how sections of a given machine or structure will look, shows in itself a mental discipline and a power of concentration of mind that is not readily attained in any other way. To see the machine work before it is built, and to put the idea upon paper exactly as it is to be constructed, involves a mental process which is not only valuable to the man performing it, but to the community at large. It is the possession of this power, however it may have been attained, that has made the great engineers.

No one thing is more striking than the interest which students take in all kinds of laboratory work, whether it be chemical, physical, or mechanical, and the evident relief and recreation which it brings to them, as a change from purely mental labor to that which occupies the eye and the hand. For the time being, they become investigators, acquiring knowledge, making researches, drawing conclusions, watching reactions, and noting the working of different principles. Their work, to them, has just as much importance as if they were original investigators instead of learning how to investigate. Laboratory work—in which the closest attention must be paid to get the

results, and the greatest accuracy is required to interpret them after they are obtained—not only gives to the student a capability for observation but a power of concentration of mind not easily obtainable in any other way; because the men are interested in obtaining results which they are themselves to interpret. They also learn the power of discriminating between things which are apparently alike and those which really are so, and of rejecting those which are of no special importance. There is, however, a real danger in this kind of work. We may cultivate such habits of precision in connection with those of observation by carrying them so far beyond their legitimate limits that a mental habit is formed which can see the point of a pin but is not able to distinguish the side of a house. We have seen such men in practical work, who, in their endeavor to avoid causes of error, introduced more sources of it than if they had made no attempt to avoid it. This, however, is a perversion of the true principle. The application of the facts learned in the class-room necessarily teaches the pupil not only to reason but to discriminate, not only between things which are true and false, but to differentiate between those which are of more or less value. It is not always easy to place the true balance between laboratory and class-room work, but it is just as necessary to train the eye, the ear, and the hand, as it is to acquire information which gives the brain the power of discrimination.

It may be said that in the schools one learns the theory, and one learns the practice in after-life—that the theory can never be learned except in the school, because in practical life there is no time for theory and it will all be practice. The old idea was, that any time devoted to laboratory work, more than a certain minimum, was wasted. The results of modern experience show that theory can be better taught in the laboratory than in the class-room, because its application follows at once on its announcement. It is thus fixed in the memory and ceases to be an abstraction. Besides, if the habit of applying knowledge is not learned in the schools it will hardly be learned outside of them, except by a long and painful experience. Both as mental recreation, and to train the powers of observation necessary for practical life, a certain number of hours each day should be devoted to laboratory practice of some kind, so that the application of the theory may be learned at the same time as the theory itself. It would be useless to waste the time of the student in the machine-shop in teaching him to file or turn with great accuracy, or to make experiments and observations which can only be performed with sufficient nicety after long practice,

because the principles upon which such work is done can be learned in a very short time. The execution of the work, however, can only be learned in the schools by such an expense of time as would not be justifiable; and while the principle will have its many applications, the engineer himself would rarely or never be called upon to perform the work. My own experience has been, that I derived as much benefit from the six months' training in the machine-shop, which was my recreation during the last year of my college course, as from my college education itself; but it is doubtful if the machine-shop would have been of such great use had it not been for the previous intellectual training. It is a mistake, into which many of our educators have fallen, to suppose that the time given to the training of the hand is lost so far as intellectual advancement is concerned. The two go hand in hand. No true education of the hand, nor successful laboratory work, can be done without training the mental faculties as well; and amongst the mental qualities acquired by such work are observation, which makes the accurate delineation of all the parts possible, and concentration of the mind upon the object being examined or discussed. In all laboratory work the principle should be to teach men how to do good work, but not to waste time after they have learned how. It is not the object of the professional school to make skilled workmen of the students. The moment they have learned how a piece of work ought to be done, they are capable of teaching those who occupy an inferior position how to execute it properly; and if this instruction has been coupled with the teaching of how to accomplish what is to be learned with the least amount of time and expense of material, they can teach other men to be skilful without necessarily being skilful themselves. It must be remembered that theory is usually acquired in the school, while practice is the question of a lifetime. It must always be kept well in view, that the object of introducing laboratory work into the schools is *in*-struction and not *con*-struction, and that when the latter is pushed beyond its legitimate limits the school becomes a shop, and that then a large amount of valuable time is sacrificed to the attainment of a skill for which there will be no use in practical life. What is wanted of the engineer is not to do work accurately with his own hands, but to know how to do good work and to recognize it when it is well done, and how to correct what has been poorly executed.

Nothing is so powerful as the force of habit. Accuracy of statement, precision of ideas, probing things to ascertain what are the

fundamental principles involved, are habits which can all be taught and encouraged in the school, and hence the formation of such habits in students should in every way be stimulated, and every possible impediment put in the way of shiftlessness, both in statement and in work. There is no better way, than by laboratory work, to form and stimulate such habits, and to make shiftlessness impossible. No better plan for doing this can be adopted than the giving of problems which the student knows to have been carefully worked out beforehand, and the results of which have been obtained from actual trial, or to execute drawings for which there is required not only accuracy, but the condition that they are to be so made that they can be used in the shops. I once saw some elaborate tests of iron and steel made in the greatest detail by officials who should have known better, where the measurement of the elongation of a piece of iron broken in the testing-machine was made by putting the two pieces end for end, and jamming them together in a vise, and then reading the elongation to thousandths. The school-training should always be such as to make such methods intolerable to the observer, however much they may be tolerated by the public. One of the greatest advantages of laboratory education is that it permits each man to be treated as an individual. No one who acquires knowledge or practice rapidly need be kept back if he works rapidly or pressed forward if he is mentally slow; every man works according to his own individual capacity and skill

I have never been an advocate of doing in the schools by the ounce what is done in practice by the ton. Playing at work and teaching what must be unlearned is a vicious principle. As well teach carpentry with miniature chisels and hammers, or machine-work with a watch-lathe, as to teach engineering with miniature appliances. The advocates of this system claim that it gives the men confidence in themselves, but what is necessary is that other men should have confidence in them, which they certainly will not have when play methods are attempted to be put into practical execution. The schools should not teach anything which the man must unlearn, and this principle is being put into practice in many of our schools now. In the old methods great discredit was brought on the schools by this necessity of unlearning. Better not learn at all, than learn what is to be acquired wrong, which is what the necessity for unlearning means. It is certain that practical experience will have to be acquired after graduation. The engineer has all his life to acquire it in. With real tools he can make a first step in the schools, so as

not to be entirely ignorant when he commences practice, and he will then have a decided advantage over those who have not had much experience; but to take up valuable time in the schools, which is the only time in his life when he can learn theory, to acquire great skill by the practice of what he must afterwards unlearn or at least greatly modify is a fatal mistake. It would be better to devote the whole time to theory and leave all the practice to be learned under that usually hard taskmaster, experience, which will be much less hard, however, if there is nothing to unlearn.

We have found the greatest possible advantage from summer schools where the students actually work in the field or the mine and apply in practice the principles they have learned. This, however, is only another phase of laboratory work, and should be carried out with discretion. The object in most of such schools is to learn how to do, more with the object of directing others rather than of practical execution with one's own hands. There is the same danger here as in laboratory work, that time may be devoted to gaining excellency of performance rather than knowledge of the thing. I knew an engineer once who devoted several months to learning how to use the pick and shovel and worked 12-hour shifts with the men. He did acquire it and gained great physical strength, which was, perhaps, some compensation to him, but no such waste of time was justified by the engineering experience he gained. When the best methods have been exemplified attention should be turned to other things. Both time and energy are often wasted in these summer schools, which should be only the entrance gate into the practical school of real life. There is a real danger that in seeking to furnish what is practical and pushing the training of the shop or laboratory or field work beyond its legitimate limits, we may lose sight of that which gives the discipline on which success in life depends; that in teaching the how we may forget the why.

The museum, to those not well acquainted with its uses and with the derivation of the word, is associated with amusement, but the ἀμουσοι were the uncultivated and the unlettered, who went to the museums, the places devoted to literature and the fine arts, with more or less of a hope of instruction as well as amusement. The museum itself was dedicated to the muses and maintained by the lovers of art, and to such a place, well arranged by the thoughtful teacher, the earnest student should be encouraged to go for aid in the study of his science, for recreation when overburdened, and for as sure

a way of reaching his end as by oral instruction or book-learning, while the mere curiosity-seeker will be sure to carry away with him from the museum, if no other idea, that of order and classification. The museum is a necessary adjunct to the technical school, because it helps to familiarize the eye with colors, forms, associations, and proportions of things with which the student must in any case become familiar. Passing by and seeing, even without study, a mineral, a chemical, a part of a machine, or its whole, will familiarize him with color, shape, and proportions in a short time without effort, as much as many hours of study and more than the memorizing of a complete description from a book. Nor is it enough that the student should see only. He should be able to handle, to look over and to examine samples and specimens, placing them in every position, so as to become familiar with all their conditions, their weights, their dimensions, their proportions. No amount of book-knowledge would make it possible to distinguish minerals which are very much alike, or even if it did, could only be acquired at the expense of an unwarranted amount of time, not in any way proportioned to the value of the knowledge acquired. Museums in a technical school should be arranged on a principle which will bring out the relations of the things they are intended to illustrate. I am strongly an advocate of making all such museums, where it is possible, passage ways through which students must walk to and fro in going to and coming from their various class rooms, and of placing on the walls of the class and lecture rooms collections where the eye may rest, even though it be for only an instant in the intervals during the interruptions of thought. The eye in this way becomes unconsciously familiarized with objects which, from their previous familiarity with them, when they commence to study them closely, do not strike the terror into the heart which an absolutely new and unfamiliar thing sometimes does, thus making the subject less difficult. The order, the arrangement and the classification of the objects exposed carry with them a most useful lesson, which is unconsciously absorbed and teaches systematic methods better than almost any other way in which they could be taught. The museum thus becomes a powerful object-teacher. Its instruction is all the more emphatic because silent, and the principles or facts which are demonstrated in the arrangement, all the more impressive because they are unconsciously learned. The student is thus without effort made to think that this or that must of course be true—we have always known it. It thus makes the acquire-

ment of certain kinds of principles easy, where they might have otherwise been difficult if this powerful object-teacher, the museum, had not been brought into play. Familarizing the eye of the student with good types makes knowledge of what is proportion almost intuitive. Beauty then becomes an element in his future design, to which his analytical knowledge will never allow him to sacrifice strength or utility. If the eye has been properly trained the drawing of a section stands out to him in relief, and he can distinguish by means of it what is behind or on one side as well as what is shown in the section or side of the relief which the drawing exhibits. There is always the danger in teaching from models, even though made to a scale, unless the idea of relative dimensions has been taught, that the real thing in its own proper scale will appear heavy and clumsy, and thus generate the habit of making things too light. This can always be guarded against by having the sections of parts of full size where they can be seen and handled. In my opinion too little is made of museum education in this country and too little floor space given to museums. They should be open throughout the entire day and be contained in well-lighted and well-ventilated rooms. The students should have free access to them at all times, and should be encouraged to pass as much time in them as is consistent with duties in other directions.

The idea of the students in old times was that the faculty was to be got ahead of by every possible means and that each and every member of it was his particular and natural enemy. Fortunately for the success of our technical schools, this idea never was firmly implanted in them and is fast disappearing. Only the shadow of it remains. The true relation of the pupil and instructor is that of searchers after truth, in the pathway of which the teacher has advanced a little beyond the pupil and is helping him to follow. With such relations there will only be a feeling of friendship or even of intimacy, and never of antagonism. The professor becomes the pupil's helper to pass the difficult places and his friend. To my mind the system of elective studies, which is so large a feature of college education has no place in the technical school. A most careful trial of it was made some years ago, under the impression that what would work in the college would work in the technical school; but it was put down by the students themselves, who declined to take "optionals," since what they wanted was as full a knowledge of the professional subjects as possible, and asserted that if a study

was optional that of itself was a declaration that it was not necessary, and that if two were "electives"* they needed both.

There are some things which are due from the instructor towards the student, as well as the student towards the instructor; and one thing is that, whatever else is done, the subject, however difficult, should not be presented in such a way as to make the student think it is so. In reviewing an old, as well as in presenting a new subject, the knowledge of the fact that the teacher is himself interested and thoroughly convinced, not only of its importance, but of the ease with which it may be acquired, goes very far towards solving many of the difficulties which the student may have. One thing is certain, that enthusiasm in the teacher begets it in the scholar. There is a magnetic power in the words of a really good lecturer that makes the attainment of knowledge seem really desirable. I remember very well, in my student days, being present at a series of lectures in a foreign language of which I could not understand more than half of the words, being so completely carried away with the enthusiasm of the lecturer that I was not only convinced that the subject, a mathematical one, was not so difficult as I had imagined, but was incited to much greater efforts to master it than I would have been from a dull lecturer had I heard the subject in the English language.

It should never be possible in the schools under any conditions for the student to acquire a smattering only, of anything. No one thing should be so severely dealt with by the instructor as the tendency to superficiality, to empiricism or to charlatanism in his pupils. He must, therefore, himself set the example by carefully mastering the subject which he has in hand, and showing that he himself is not only interested in the problem which he is elucidating, but really desirous that they should master it, which will not only beget in the student accuracy if he is accurate, interest if he is interested, but a desire on his part to master, as far as is practicable, the details, instead of acquiring only what is just sufficient for the passage of an examination. Such an example in the teacher stimulates a real desire on the part of the pupil for intellectual as well as moral honesty, which will tend to make the man in the practice of his profession honest not only in act but in thought. The enthusiasm of

* By "electives" are understood the studies, of which a certain number must be pursued by the student, and by optional the studies, outside of the elective list, which may be chosen or declined at will.

the lecturer is very catching, and no one distinguishes more quickly the perfunctory spirit than the student.

I remember, many years ago, being witness to two of the most flagrant abuses of the power of memory, both of which occurred in the mathematical class-room. In one of these classes the teacher required that the problems of Euclid should be mastered *verbatim*, so that not only the demonstration should be made in the identical words, but also that the angles should have the letters exactly in the same order. A B C was right, but C B A was wrong. The other was, where the teacher was satisfied if just half the problem was learned, and allowed his pupil to stop in the middle of an angle, if that was just half of the letter-press of the demonstration Such methods are beyond and beneath criticism. These men seemed to think that brain-development was gained by loading the memory with words. In both cases, as was natural, the teacher lost not only the confidence but the respect of his class, and after thirty-five years I still occasionally hear them spoken of, but without respect. It is greatly to be feared that the exercise of the memory only, is often fostered by the use of text-books from which the words and not the principles they involve may be learned, and that some of the same spirit is still extant. The mere acquirement of words, which consists of memorizing, may be beneficial to style in writing, if good examples are selected, but it is most prejudicial to originality of thought, and ought to be discouraged. Every student ought to be able to tell what he knows in his own language, for fear that he may have mastered words only and not ideas.

One of the greatest difficulties in the education which consists of injecting into the brain instead of developing its powers by drawing out of it, is that so many things are forced upon the mind that it is incapable of receiving, that it cannot hold them, and hence the system of cram, which brings about one of the very worst phases of intellectual decadence, the inefficient and the superficial man. The day when it was the object of the student to cheat the professor has long passed, but there are a few dishonest practices which remain in our schools, partly as a heritage of the past and partly as an indication that the old Adam has not been entirely removed. It is perfectly possible for the teacher to show that unfaithful work brings its own reward in uncertain knowledge and untruthful ideas; that leaving to-day's work to be done to-morrow, makes it almost impossible to do either day's work well, and fosters the habit of being content with work poorly done, or of trusting to luck, which makes

men unmanly and dishonest to themselves. Want of a proper respect for the teacher often grows out of the habit of demanding excuses in petty things, too much watching and not enough trust in the true manliness of the pupil. It is the student who makes the engineer, and if the manliness of the pupil has not been previously sufficiently developed, so that he remains a boy, while receiving a man's education, he has commenced his professional training too young, and should be returned to the preparatory school.

Cribbing is one of the dishonest practices of our schools, and the stopping of it has, for a long time, been the subject of the most careful consideration of both teachers and pupils. In the endeavor to produce a high standard in some of our schools, the pupils themselves have invented and carried out a police arrangement amongst each other against it, as being a dishonest and unmanly practice to such an extent that within certain limits they can be trusted, though too strong temptation should not be placed in their way. If the student is made to understand that "cribbing," written or spoken, makes him a living lie, there would be less of it, but I fear most students think, until taught differently, that "the end justifies the means." Another, and quite as dishonest, although a perfectly useless practice, is that of guessing. Almost every instructor knows when a student is going to guess before he opens his mouth, and in some of our schools this practice has been so far discouraged that the pupil will in a frank and manly way own at once that he does not know rather than to be so unmanly as to guess. The teacher who allows his pupil to guess is not only allowing him to do an unmanly thing, but is encouraging in him the dishonest idea that he may trust to inspiration instead of legitimate work and may at times impose on his hearers a pretence of superior knowledge which they may not discover. But this habit if not discovered at the time, must be eventually, and to tolerate it is to encourage him not only in present deceit, but in cultivating for himself uncertain and unfaithful methods. Whatever else is done, deliberation must be encouraged, and haste discouraged. One thing must be thoroughly impressed upon the mind, that no good work can ever be done in a hurry. The effect of hurry in intellectual work is like that of patchwork in a machine; it may be made to hold together, but it never can be symmetrical and there will always be the danger that at some time some of the parts not well matched will give way, and the result will be disaster.

If it is possible to check the desire, which has been fostered so

many years by our systems of education, of acquiring knowledge simply for the purpose of passing an examination, and not in the interest of mental development, it should be done. The highest compliment ever paid to the course in the institution which I represent was that of a young man who was then already a distinguished mathematician, and who had intended to devote his life exclusively to the study of mathematics, who came to the school, as he said, not that he ever expected to apply what he could learn there, but for the mental discipline which, from careful examination of the course, he was sure he would gain from the arrangement of the studies. We ascertain what progress the men are making by examinations which are conducted in three ways; they are practical, written or oral. While there are advantages in the oral method of examination for well-prepared men who have complete control of themselves at all times, practical work or the written examination seems to me to be the fairest, provided that the subjects to be discussed require some originality of thought in the student. I have always been in favor of giving problems which involve the principles taught, but which are not directly treated in the course of instruction. While it is not always possible to do this, yet the principle can be carried out. A written examination, made in this way, is a fairer test of the capacity of the student than an oral one can possibly be. It forces him to classify his knowledge and prevents him from the parrot-like use of his memory. In laboratory examinations, where there is something to be done, this is always the principle on which the examination must be conducted, and it seems to me to be the best method for the theoretical part also.

It is altogether improper to make the passing of examinations the only test of a student's qualifications. I have in mind two men, one of whom I knew to be qualified, but who failed in his examination from nervousness, resulting from overwork; and one whom I knew not to be qualified, who passed with great credit. Under the old law the best man had to pass his examination over again, much to the mortification of himself and his professors. But the luck of the other one followed him for only a short time, and in his future career he showed failures both of ability and character, while the man who failed from nervousness occupies and always will occupy an extremely creditable position in the profession. Yet the student under examination has the right to the credit for what he does, but there should be such checks and safeguards as will give to the examination a coefficient only.

A point which requires attention, and should always be a subject of instruction, is the method of estimating the values of different kinds of work as well as their stability. The item of cost is the first which confronts the engineer in life. The question of the possibility of construction constantly occurs in the experience of old engineers and is one of the first questions which presents itself to the young man entering his profession. If he has had no instruction upon such questions, he must find this out for himself, but it would be much simpler and better if instruction were given in it as well as in other business matters connected with the profession. A knowledge of general bookkeeping should be required for entrance, but as the details of keeping accounts for each specialty can only be applied to it, they should be discussed as the matter is gone over in the lecture, and their peculiarities presented.

It is not to be forgotten that one of the most important things for the engineer is to avoid not only waste of material but of time. One is as much a part of the cost as the other. One of the best methods of teaching this in the schools is the setting of tasks to be accomplished in a given time, and in the shops of making certain things with a given amount of material. This may be done to ascertain what the capacity for work of the individual is, and by stimulating the habits of attention and rapid and accurate thinking, to bring up those who are mentally slow to work in competition with those who are more brilliant and rapid. There is no doubt that the rapidity of thought may be stimulated in the slow individual without of necessity decreasing his accuracy. One of the greatest advantages of laboratory work of all kinds is that it is full of the possibilities of such problems. The difficult problem to deal with is with those who do not think, but such material as this would be soon weeded out of almost any of our technical schools.

The health side of the question must not be forgotten. No education, however complete, avails anything unless the body is healthy, and there should, therefore, not only be such an arrangement of studies that recreation should be constantly afforded by change of work, but there should also be some provision made for moderate bodily exercise, which is necessary to every healthful mind. Whatever excess of energy the student has, its use should be encouraged out-of-doors. I have always believed that recreation for the student in school hours could always be accomplished perfectly by judicious change of work, and that exercise, to be healthful, should be in the open air more than in buildings. There is always danger that exer-

cise in-doors will be carried to excess. If gymnasiums are furnished, or out-door sports encouraged, the exercise should always be carried on under the direction of a wise physician.

I think, as I have said on a former occasion, that the characteristic of our American schools is, that the instruction given in them leads men not only to form a judgment, but an independent one;* to form opinions for themselves, and yet not to pass by the results of the experience of others. This is exactly the difference between the teaching of our own schools and those of some foreign countries. There the judgment is rather that of the chief, with whom it is often dangerous to differ than of the individual, and hence the young man knows but little of mental liberty and independence. He is expected to receive his opinions on authority, not to form them for himself, and hence there is a tendency to a want of self-reliance and a habit of hesitating about advancing an opinion which may be overruled, which is fatal to self-reliance. The value of any education, however, does not depend so much upon the facts learned, the quantity or quality of the opinions absorbed and the amount of knowledge gained, as on the power of reasoning acquired; not the amount actually stored in the mind, but the knowledge of how to use it and confidence in the ability to do so, and where to go to find what is not known, or get the information relating to any series of facts when it is wanted. Hence the student must be taught to think for himself, so that as an engineer he may have his own independent judgment and not be constantly asking himself where shall I go to get an opinion to follow.

The old theory that the beautiful statue exists in the stone, and requires only skilful sculptor to extract it, is certainly true of men. The materials are all there: it requires only the skilful educator to bring them out; and just as the sculptor sees the statue in the stone or the mechanic sees in the irregularly shaped piece of iron the finely-finished part of the machine, working in its proper place, so should the educator be able to train young men in the duties of their profession, making them symmetrical both in their mental and physical acquirements, bringing out the faculties they have, and developing those that require expression or expansion, so as to make the symmetrical man. With men in large classes this can hardly be done, hence numbers may be a sign of weakness, and really are so, unless the standard is high and the force at command

* Discussion on Technical Education, p. 98.

is sufficiently large to ensure the treatment of each man as an individual, and not as only one of a large number.

Unlike the ordinary university graduate, the engineer leaves the schools for practical life-work. He has to deal at once with problems that require the immediate use of nearly all the faculties which can be educated, and not a part of them. His hands are required to do, his ears to hear, and his tongue to direct; and without the proper training, the systematic equalization of the powers required to effect this, he becomes in his practical life a one-sided man, and is likely to remain so unless he has the unusual power of first seeing and then correcting these defects.

The success of the engineer in life depends as much on his character as his education. The old theory of only putting knowledge in, did not develop character to any very great extent, but the real purpose of bringing out what there was in a man, and cultivating any germ of talent, however small, not only does develop the character, but the mental faculties, which will always seek the practical application, as the old process never did or could. The administration of affairs, and the management and control of men, are as necessary to the engineer as the application of his technical knowledge. These can only be acquired to a very moderate degree in the schools. They are not the places where commercial rules are to be learned. Relative facts only can be taught there. The positive relations of labor, material, wear and tear, are likely to be the same everywhere when the conditions are the same, but commercial relations will be different. To be a good executive officer cannot be taught in the schools; it is to be learned by contact with men, whether it is to be the control of intellect or of mere labor; but the reasoning powers which are developed in the constant application of facts which are learned to practical work, and which must be made by the eye, the ear, and the hand, give the power of discrimination and reasoning which should make it more possible and easy for men scientifically educated to acquire this control than for other men. It is as much a knowledge of one's own as of other men's character that leads to the ability which successfully manages men. Kindliness of heart and a real interest in his men is what they discover rapidly, and if this is coupled with firmness the questions between the men and the employer will rarely if ever cause real difficulty.

As the engineer has to do with natural forces, which control the phenomena he has to study in nature, and which he must, in a cer-

tain sense, control in his working, he must learn in his studies to discriminate between those forces which are essential to his work and those which are only a by-play in it. This careful observation leads to the neglecting of unimportant things, and to the placing prominently, not only in the mind but in the actual execution of the work, of those things which are the controlling ideas and forces by which the work is to be governed.

There is a great advantage in scientific education. It deals with facts as well as theories. A thing must be true, or it is false. In the continued search after facts, the accurate statement which truth requires not only develops the mind, but the character must be influenced more or less to the desire for high and still higher aims in life. No search after truth can be made without a theory. The results of research show this theory to be true or false, and, as the object is truth, the moment the facts will not bear out the theory it is discarded. How different the result of metaphysical discussion; everything there is bent on sustaining the theory; subtleness of reasoning becomes its aim. It is true there are no facts directly affecting human happiness in the results of its discussion, but the higher character must be formed by the continual search after truth occasioned by the constant desire to ascertain what is fact.

There are things in the profession of an engineer which make him necessarily more accurate than other men. The knowledge that, in all branches of the profession he may be called upon at any time to face danger, and is liable at any moment to be brought into contact with facts, a mistake in the detection of the minutest character of which may at any time cost his own or the life of another man, forces the habit of coolness under trying circumstances and should make him truthful to himself and to others. The knowledge that he cannot run away, but that it is his duty to remain in times of trial, makes him brave and capable of facing danger as he would face any other fact in his professional experience. The highest devotion to duty leads to the result of the world's being better for one's having lived in it, and ambition should be towards contributing to the sum of human knowledge rather than towards money success in professional practice, but the attainment of both is quite possible.

The great engineers who made the end of the last century and the beginning of this famous, spent the greater part of their lives in acquiring the knowledge which we teach every student in our schools. We do not say what these men might have been with a technical-school training, but certainly the young graduate of to-day starts with

very great advantages over them. Whether or not this century, with technical schools, will do as much for engineering as the last century without, remains to be seen; but it is certain that the knowledge of these subjects is much more diffused than it formerly was, and that mankind as a whole is receiving a benefit which was not possible when there were so few engineers that every one who carried out any large undertaking became of necessity a great man.

There is a great advantage for the student in becoming acquainted before he enters his professional career with the words in which the mechanic expresses his thoughts, or, in other words, the terminology of the shops. It gives confidence on both sides, to the mechanic as well as the student, makes the language of each intelligible to the other, and makes the mechanic feel that he and the engineer are on a more equal footing. I have, on a former occasion,* entered a plea for the laborer, and especially for the skilled laborer, who has learned by long experience to correct by his eye and to do with his hands in the workshop what really entitles him to respect. The man who depreciates and looks down upon manual skill, underrates the first principles of engineering. It is the contempt of it which has kept the world back, and has been indirectly the ruin of many an intellect which, if its ideas had been allowed to come out of the brain through the hands, might have contributed materially to the advancement of the world. There is a great difference between this century and those which preceded it, in the respect into which skilled mechanics have risen in the eyes of the community, and the thorough appreciation of their work which the world to-day accords. It has usually been the case that the great inventions which have startled the world at the time, and have resulted in great progress amongst communities and nations, have come more from the training of the hand than they have from the old-fashioned training of the schools.

After graduation there is apt to come a period of discouragement, when lucrative employment does not come; and this is the trying time when character is developed. To find out how to apply what he knows, to turn his theory to some use, to find out exactly what niche he is made to fill in the world's mental and industrial progress, is the most difficult and trying problem of a young man's life. The old motto, "I will find a way or *make* one," should be the principle of every young man starting in life. There are plenty of professional rewards for those who have the courage and the manliness to win them. Those who have had the greatest amount of influ-

* Discussion on Technical Education, p. 100.

ence in procuring places at the start have not always been those who have been the most successful in their professional career. The greatest men have been the engineers of their own fortunes as well as great engineers in their own profession. Discouragement never accomplishes anything, but continual trying does. The power of not knowing how to be discouraged is enviable in all men, and this is one of the few things of which it is well to be ignorant. It is very essential that the young engineer should not despise the day of small things, nor the careful observation of them. It has generally been by slow steps, and the careful observation of minute things, that the greatest discoveries have been made. Nothing is too small for the intelligent engineer to investigate; behind it may hide some great principle.

We have in this country multitudes of institutions whose only province appears to be to crowd the brain with theories and facts already known. How few are those whose function it is to add to the sum of human knowledge. We ought to train, if possible, our engineers not only to learn and apply facts already known, but to seek to add to the sum of human knowledge by investigations into what is not known. It is a great lack in our methods of education in that there are no schools for training investigators. Any one can get results, but few men can tell what they mean or what their relations are to each other, or to similar facts. To the education and training of men who have this faculty, which is a very uncommon one, time ought to be devoted, for the quality of mind which they have is very rare, and can only be raised to its greatest value when it has been carefully trained. It is astonishing that the "adding to the sum of human knowledge" has attracted so little attention, and that so few endowments have been made for the purpose. What more permanent monument to one's memory could be devised, or what better use of his fortune could be made, than to have it said of him, as was once said, I have made these investigations "a daily pensioner on the bounty of one who entered into rest more than five hundred years ago."* The memory of such a man would never die, and truly his good deeds would live after him.

The introductions into our common schools of such methods as have made technical schools successful would, in my opinion, go further to solve the labor-troubles than any other means yet proposed. If a part of the time, spent in the schools in learning the "three Rs," had been spent in directing the pupil how to use his

* A Plain Commentary, vol. i, p. xvi. Philadelphia, 1856.

hands, I am certain that the result would be greatly to the benefit of mankind as well as the individual, and I am also sure that if part of the large amount of time spent in the preliminaries of learning to write, had been spent in learning to draw, the pupil would have learned not only to write better, but to express himself in a language that could be understood by everybody. Skilled labor is, of necessity, conservative, and not likely to lend itself to either lawlessness or riot. Unskilled labor is, in general, ready for revolution on the theory that almost any change must be for the better. By our present method, the children of the hewers of wood and the drawers of water are, to a great extent, unfitted for the situations in life which they occupy, and not fitted for any other. They cannot be blamed for the idea that they should occupy positions for which the school-training has not fitted them, for since the common school has taught them to despise all labor but that of the brain, and this function only has been trained, they think themselves fitted to occupy any position. They have not been taught to honor manual labor. They see in it only toil and small rewards. How different might it have been, had they been taught, as inspiration enjoins, "Whatsoever thy *hand* findeth to do, do it with thy might."* They have read this plain injunction many times, but their education has taught them to substitute *brain* for *hand*, and the precept is as unintelligible to them as if it was written in the original Hebrew.

The world is full of laborers. We are all such, but the uneducated classes are unable to obtain their living in any other way than by what is called manual labor. Against the reproach connected with this designation, I must here enter a protest. These men *toil* with their hands, because they do not know how to use them intelligently. It is frequently said that anybody can dig, which is true; but the production of the greatest economical value of the labor expended in raising a certain amount of earth on a shovel with the hands may be nearly double as between one man and another, if the useful effect of the kilogrammeters of force expended is to be considered. I hold that the appellation "manual labor," which usually carries with it a certain stigma, is only used because the laborer does not know how to use his hands. His labor is toil, the mere exercise of brute force, because it has not been educated, and he feels degraded by it. When it has been educated he no longer despises his labor; it has become the exercise of skill, and he both respects himself and demands and receives re-

* Ecclesiastes, ix, 10.

spect from others. Manual labor skillfully performed is often as worthy of regard as intellectual achievements, and we acknowledge this in the respect we have for and the wages we pay to the skilled mechanic. The world is lost in admiration at the works of its sculptors, painters, and musicians. Why should painting, sculpture, and music monopolize the rewards of manual skill? Why should not every human being be taught to use his hands and eyes? It is certainly more useful and more necessary than the memorizing of many of the things taught in our public schools, which do not give equal mental discipline, and cause the man and boy who have no reliance but the sweat of their brow to gain their livelihood, to look down on the labor of their hands. Why should hand-work, if well done, be any more disgraceful than the work of any other part of the body? How much are we to blame for the discontent of labor when we ourselves have indirectly taught in our public schools that the labor of the brain is the only labor that is not disgraceful? We have driven a great part of what would be our most intelligent labor from the fields to fill the precarious positions of clerks in our large towns and cities, when the educated farmer is what the country most needs, and the one upon whom the country most depends in time of real danger. There is little reproach to be cast on the methods of our engineering schools. Every one of them may be improved in detail, but their general method has always been successful, because it tends to the harmonious development of the whole man. Why should we not adopt a similar system in all of our schools?

The only true principle of education is the symmetrical development of all the powers, which the intellect governs, or, in other words, the harmonious development of both the intellectual and physical faculties.